Space Technology Research Grants

Frequency Tunable Piezoelectric Energy Harvester based on Crumpled MoS2 and Graphene

Completed Technology Project (2017 - 2021)

Project Introduction

As most space missions are long-term, some lasting decades, and will be conducted entirely remotely, power generation issues become crucial especially given the constraints on power sources like fuel or energy harvesting systems on spacecraft. Conventionally used batteries are bulky, which sharply increases the mass of spacecraft and limits the amount of equipment that can be included on spacecraft, they pose a danger of explosion, are inconvenient to recharge, and suffer from limited life time. As a result, the development of light weight energy generation devices with high power outputs and low-cost is essential. Harvesting ambient energy is a possible solution to extend the limit of power production in space. Many researchers, including researchers at NASA, have been working on energy harvesters to convert vibration energy into usable electric energy based on piezoelectric materials. In comparison with previously fabricated nanowire- and nanofilm-based nanogenerators, nanogenerators based on a single layer of MoS2 have the advantage of withstanding enormous strains, while being light weight and possessing a high stiffness and high surface area to volume ratio. Thus, improvements on existing technology including greater efficiency, compact size and increased durability can be realized. These advancements in power generation enabled by nanomaterials will increase the capability of space missions extending lifetime and increasing scope. Herein is proposed a flexible, frequency-tunable, light weight, high efficiency, and radiation tolerant structural piezoelectric energy harvester based on overlap structures of crumpled MoS2 and graphene that resonate in a longitudinal direction. In order to increase the performance of flexible harvesting devices using MoS2, it is highly desirable to utilize the longitudinal electromechanical coupling coefficient and piezoelectric voltage constant due to the large displacements along the longitudinal direction. The proposed energy harvester is based a spring and mass system. Each crumpled monolayer MoS2-graphene pair is clamped on the opposite sides of a proof mass and the crumpled monolayer of piezoelectric MoS2 act as a spring in this system. This system enables the conversion of external vibration to longitudinal vibration of the central proof mass. This longitudinal vibration induces strains, compressive on one side and tensile on the other, on both piezoelectric monolayers of MoS2. Power generation can be achieved by deriving a current from the potential difference between the two piezoelectric monolayers of MoS2. The system resonant frequency results from the effective mechanical stiffness which is dependent on the mechanical properties of the crumpled MoS2. This resonance will result in maximum longitudinal wave propagation when the system experiences vibrations on resonance, leading to the maximum potential difference between the piezoelectric monolayer MoS2 pairs. In this regard, the proposed energy harvester is designed to have frequency-tunability, by controlling the crumpling of the MoS2 monolayers, improving power output. To realize the proposed system, there are four key research objectives. First we will pursue fundamental studies on (1) the effect of crumpling on the effective mechanical stiffness of MoS2 and (2) the effect of crumpling on the piezoelectric

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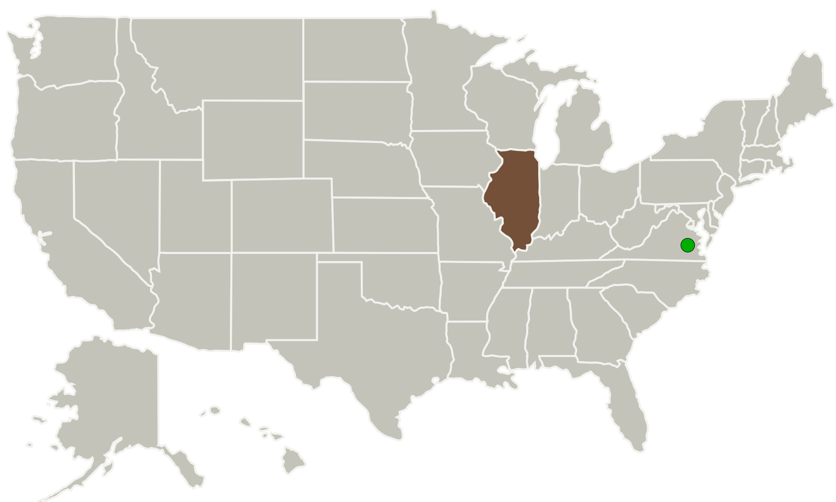
coefficient of MoS2. We will then (3) investigate the power generation response to different modes of vibration frequencies. This is important because, in real world systems, nanogenerators are subject to far more varied modes of vibrations. Investigation of the proposed devices response to different modes of vibration frequencies will be used to confirm the frequency tunability of our energy harvester and compare its energy conversion efficiency to existing technologies. (4) The final goal of this this project will be integration of multiple arrays into a full comprehensive structural, flexible energy harvester.

Anticipated Benefits

In comparison with previously fabricated nanowire- and nanofilm-based nanogenerators, nanogenerators based on a single layer of MoS2 have the advantage of withstanding enormous strains, while being light weight and possessing a high stiffness and high surface area to volume ratio. Thus, improvements on existing technology including greater efficiency, compact size and increased durability can be realized. These advancements in power generation enabled by nanomaterials will increase the capability of space missions extending lifetime and increasing scope.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Illinois at Urbana-Champaign

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Sungwoo Nam

Co-Investigator:

Chullhee Cho

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Organizations Performing Work	**Role**	**Type**	**Location**
University of Illinois at Urbana-Champaign	Lead Organization	Academia	Urbana, Illinois
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

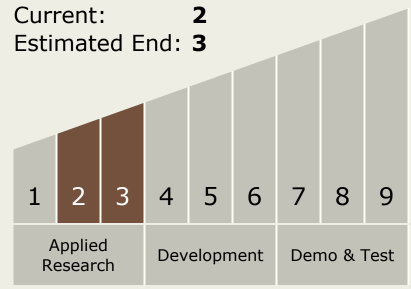
Primary U.S. Work Locations
Illinois

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.1 Materials
    └ TX12.1.6 Materials for Electrical Power Generation, Energy Storage, Power Distribution and Electrical Machines

Target Destinations

The Moon, Mars, Others Inside the Solar System